NASA SBIR 2006 Phase I Solicitation

X9 Propulsion and Propellant Storage

The Exploration Systems architecture presents some propulsion challenges that require new technologies to be developed. Some of these technologies are affordable high reliability booster engines; long term cryogenic propellant storage, management, and acquisition; deep throttle cryogenic propellant space engines; cryogenic propellant reaction control engines; and non-toxic storable propellant space engines. Furthermore, specific technologies are required in valves, regulators, combustion devices, turbopumps, ignition, instrumentation, modeling, controls, materials and structures, pressurization, mass gauging, and cryogenic fluid management. The anticipated technologies to be proposed are expected to be capable of being made flight qualified and certified for the flight systems and dates to meet mission requirements.

Subtopics

X9.01 Long Term Cryogenic Propellant Storage, Management, and Acquisition

Lead Center: GRC

Participating Center(s): ARC, GSFC, JSC, MSFC

This subtopic includes technologies for long term cryogenic propellant storage, management and acquisition applications in-space as well as on the lunar surface. These technologies will impact cryogenic systems for space transportation orbit transfer vehicles, space power systems, spaceports, spacesuits, lunar habitation systems, robotics, and in situ propellant systems. Each of these applications has unique performance requirements that need to be met. The sizes of these systems range from the small (3 for supercritical air and payload cooling) to very large (> 3400 m^3 for LOX and LH_2 propellant storage). Advanced cryogenic technologies are being solicited for all these applications. Proposed technologies should offer enhanced safety, reliability, or economic efficiency over current state-of-the-art, or should feature enabling technologies to allow NASA to meet future space exploration goals.

Technology focus areas are divided as follows: fluid transfer/liquid acquisition devices, mass gauging/advanced instrumentation, passive systems, storage and distribution components, and refrigeration systems. Innovative concepts are requested for cryogenic insulation systems, fluid system components, and instrumentation. Cryogenic propellants such as hydrogen, methane, and oxygen are required for many current and future space missions. Operating efficiency and reliability of these cryogenic systems must be improved considering the launch environment, operations in a space environment, and system life, cost, and safety. This subtopic solicits unique and innovative concepts in the following technologies:

Fluid Transfer/Liquid Acquisition Devices

Liquid acquisition devices capable of preventing gas ingestion into engine feed lines in low gravity, analytical models of LAD's to predict LAD performance in low gravity and to determine the effect of autogenous/non-autogenous pressurants on LAD wicking capability, techniques to minimize vaporization inside the LAD channel caused by incident heating through tank wall/lines and/or changes in tank pressure.

Mass Gauging/Advanced Instrumentation

Methods of determining liquid quantity gauging in propellant tanks in low gravity, high accuracy differential pressure transducers which can operate submerged in liquid cryogen and in-space fluid leak detectors.

Passive Systems

Advanced insulation technology including low loss cryogenic propellant tank penetrations and insulation materials capable of retaining structural integrity while accommodating large operating temperatures ranging from cryogenic to elevated temperature conditions, advanced tank support systems capable of supporting tanks during the launch environment, but decoupling on on-orbit to minimize thermal loads and passive thermal control designs for cryogenic fluid storage on the lunar surface.

Storage and Distribution Components

Advanced low-gravity submersible pumps and helium compressors designed specifically for in-space cryogenic operation, low heat leak cryogenic quick disconnects capable of sealing against the vacuum of space, long-life, low power valves for LO_2 and LH_2 capable of sealing at cryogenic temperatures, being cycled many times without consuming pressurant gas and with minimal thermal loss and pressure drop.

Refrigeration Systems

Advanced LO_2 and LH_2 cryocooler concepts for in-space operation that are reliable, lightweight, low input power and capable of removing 5 to 10 watts of heat at 77 K and at 20 K, respectively, concepts to integrate Broad Area Cooling (removing heat over large areas and long distances) into in-space storage of LO_2 and/or LH_2 and heat exchanger designs for large-scale storage systems designed densification of LO_2 and LH_2.

X9.02 Innovative Booster Engine Manufacturing, Components, and Health Management

Lead Center: MSFC

The goal of this subtopic is the development of innovative components, manufacturing techniques, health management systems, and design and analysis tools for boost propulsion. Although solid or hybrid rocket propulsion is specifically emphasized, compelling proposals related to liquid engine boost propulsion are also invited. Technologies that would contribute to increased mass fraction and decreased sensitivity to manufacturing and handling effects are particularly welcome, as are those that would reduce the time, cost, and complexity associated with designing and manufacturing large booster rockets. Specific areas of interest include:

- Concepts for solid or hybrid propulsion systems and related components that would lead to increased payload mass fraction over current solid rocket motors;
- Concepts for solid or hybrid auxiliary propulsion systems that can be throttled to provide enhanced vehicle maneuverability;
- Health management technologies, including embedded sensors and modeling methodologies, that would improve the ability to monitor the reliability of solid or hybrid rockets during manufacturing, handling, and flight;
- Manufacturing techniques that allow for reductions in the cost and schedule required to fabricate and test solid or hybrid rockets;
- Propulsion system concepts, components, and fabrication processes designed to reduce the production costs of liquid propellant rocket engines for large expendable boosters;
- Improved design and analysis tools that enhance the engineering evaluation of advanced chemical propulsion system concepts;
- Test data that provides for validation of existing design and analysis tools; and
- New propellant ingredients or formulations that would increase the propellant specific impulse while maintaining a Department of Transportation Class 1.3 hazard classification. Proposals that would experimentally synthesize and characterize new ingredients, or formulate and demonstrate new propellants, are highly encouraged, whereas proposals that rely heavily on the screening of potential new ingredients by quantum chemistry or other computational and theoretical methods are discouraged.

Proposals that address more than one of these items are highly encouraged.

X9.03 Cryogenic and Non-Toxic Storable Propellant Space Engines

Lead Center: GRC

Participating Center(s): JSC

This subtopic intends to examine a range of key technology options associated with cryogenic and non-toxic storable propellant space engines. This engine technology is solicited for use in lieu of the toxic but currently operational nitrogen tetroxide and monomethylhydrazine engine technology, which has recently seen performance improvements from 310 to 325 seconds of specific impulse using advanced rhenium thrust chamber technology. Performance improvements are a consideration, but are not the main objective of this solicitation. The Space Shuttle Orbiter Upgrade Program identified non-toxic reaction control system (RCS) propulsion as a key technology to reduce vehicle operations costs on the ground, and estimated that a significant reduction in RCS propulsion system cost is possible by the use of non-toxic propellants. In addition, the use of astronaut extravehicular activity for in-space refueling of space systems or the refueling of vehicles with humans aboard such as the International Space Station is extremely hazardous with toxic propellants. These safety concerns drive mission planners to the use of more costly propulsion modules that are fueled and sealed on the ground.

The general objectives of this solicitation derive from the NASA goals of safe, reliable, affordable and effective human and robotic missions in support of the overall U.S. Vision for Space Exploration. Successful proposals will be focused investments that systematically validate and/or invalidate key technologies and design concepts that might transform how the U.S. will pursue future space exploration goals.

The specific technology to be supported by this subtopic is multi-use in-space cryogenic and non-toxic storable propellant rockets. This technology includes the development and demonstration of key operational and performance characteristics of a range of new space engines, i.e., orbit transfer, descent, ascent, and pulsing attitude control engines. These engines can be compatible with the future use of in situ propellants such as oxygen and hydrogen or methane, but propellants consistent with low cost ground operations such as ethanol, JP-5 and nitrous oxide and monopropellants are also solicited.

Proposals are solicited for both thruster development and thruster component technologies such as, but not limited to, long-life, highly reliable ignition systems, durable, low-mass propellant injectors, and long-life combustion chamber designs. Proposals are also solicited for propulsion system component technologies such as valves, instrumentation, controls, multi-purpose structures and both electric and turbine driven pumps. Examples include, but are not limited to, highly-reliable, long-life, fast-acting cryogenic valves that tolerate high thermal loading due to heat soak-back in low-thrust, pulsing propulsion systems; cryogenic instrumentation such as pressure and temperature sensors that will operate for months/years instead of hours; and high-reliability, long-life turbopump bearings. Technologies are also solicited that enable deep-throttling turbopumps to operate at off-design flow coefficients while eliminating flow instabilities such as cavitating surge. Examples include, but are not limited to, inducer designs that can operate with a high degree of vapor content or cavitation in the propellant flow and pump diffusion systems with reduced sensitivity to flow separations. Strategies for engine and component protection from dust, radiation, and other environmental effects are also solicited. Finally, proposals are solicited for modeling efforts that enable reduced thruster development costs and schedules.

X9.04 Nuclear Thermal Propulsion

Lead Center: GRC

Participating Center(s): MSFC

NASA is interested in the development of critical technologies for first in-space applications of solid core nuclear thermal propulsion (NTP) systems for use in future human exploration missions. For short round trip missions to Mars, NTP systems may be enabling by helping to reduce launch mass to reasonable values and by also increasing the payload delivered for Mars human exploration missions.

Preliminary solid core NTP system concepts could be based on a high thrust/high Isp (~850 - 950s) NTP system that would use a fission reactor with U-235 fuel as its source of thermal energy. During the short primary propulsion maneuvers of a typical conceptual mission, large quantities of thermal power (100's of MWt) would be produced within the NTP system and removed using LH_2 propellant that is pumped through the engine's reactor core. The superheated hydrogen gas is then exhausted out the engine's nozzle to generate thrust. Representative ranges of engine performance include: (1) hydrogen exhaust temperatures ~2500 - 2900 K, (2) propellant flow rates ~7 - 13 kg/s, (3) chamber pressures ~500 - 1500 psi, and (4) nozzle expansion area ratio ~200:1 - 500:1.

Proposals are sought to further improve factors contributing to safety, performance, reliability, and life as well as reduce projected weight and costs for the first in-space NTP systems, subsystems, and components beyond that in previously achieved ground test systems. Proposals are solicited in the following key technology/concept areas:

- High temperature, low burn-up carbide- and ceramic-metallic (cermet)-based nuclear fuels with improved coatings and/or claddings to reduce fission product gas release into the engine's H_2 exhaust stream;
- Reliable, high temperature materials, fabrication techniques, and concepts for non-reactor portions of NTP systems;
- Light-weight, multi-use shielding materials and designs;
- High temperature, radiation tolerant instrumentation and avionics for engine health monitoring. Non-invasive designs for measuring neutron flux (outside of reactor), chamber temperature, operating pressure, and H_2 propellant flow rates over wide range of temperatures are desired;
- Long life, lightweight, reliable hydrogen turbopump designs and technologies;
- Lightweight, long life, high heat flux thrust chambers, regenerative-cooled nozzles and radiation-cooled skirt extensions that are compatible with hot hydrogen;
- Radiation tolerant materials compatible with above engine subsystem applications and operating environments.